Four years operations of Inter-satellite (ISLs) and Space-Ground (SGLs) Optical links

Patricia Martín Pimentel[1], Nils Hoepcke[2], Christoph Seiter[3], Karen Saucke[4], Frank Heine[5], Matthias Motzigemba[6], Siegbert Martin[7]

Tesat Spacecom, Gerberstr. 49, 71522 Backnang, Germany

Edoardo Benzi[8]

European Space Agency, ESTEC, Noordwijk, The Netherlands

Gregor Rossmanith[9], Sven Kuhlmann[10]

German Space Operations Center (GSOC), German Aerospace Center (DLR), Oberpfaffenhofen, 82234 Wessling, Germany

and

Michael Lutzer[11], Rolf Meyer[12]

Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), 53227 Bonn, Germany

During the past four years, the laser communication terminal on board of Alphasat GEO-stationary satellite has achieved the successful execution of more than 1300 optical links which implies more than 24.000 tasks for the planning system. This laser terminal in combination with a Ka-Band system constitutes the TDP1 technology demonstrator.

Approximately half of the links were inter-satellite optical links, using the Sentinels low orbit satellites of the EU Copernicus program (S1A, S1B, S2A and S2B) as communication partner with the aim of supporting in orbit commissioning activities and TDP1 experimentation purposes.

The other half of the links used the transportable adaptive optical ground station of the DLR (T-AOGS [2]) located currently at Tenerife, Spain as counter terminal. These optical satellite to ground links prepare the way not only to GEO feeder links, but also for connecting the space segment to HAPs, airborne terminals or LEO direct to earth links. In contrast to pure inter satellite links the satellite to ground links involve the atmosphere and local weather conditions. Adopting the operational concept established for inter satellite links, a certain percentage of the planned links cannot be conducted (e.g. due to clouds). The conducted links were used to characterizing the T-AOGS, characterize the atmospheric conditions as well as optimize and test coding schemes. Most of the tasks executed by the LCTs and the Ka-Band have been based in the TESAT input delivered to the MCC (operated by DLR GSOC), further processed and finally transferred to the spacecraft control center.

I. Nomenclature

GEO = *Geostationary Earth Orbit*
HAP = *High Altitude Platform*
LEO = *Low Earth Orbit*
LCT = *Laser Communication Terminal*
MCC = *Mission Control Center*
MOIS = *Manufacturing and Operations Information System*
PPF = *Principal Parameter Files*
T-AOGS = *Transportable Optical Ground Station*
TC =*Telecommand*
TM =*Telemetry*

II. Introduction

The development of LCTs technology has triggered in parallel the implementation of a more sophisticated commanding and monitoring system TDP1 is a technological system and some of the commercial requirements like reliability are not applied, but flexibility for implementing modifications and supporting fast recovery actions are mandatory. Due to the amount of tasks to be planned and the responsibility implied, a more automated and free of manual error system is desired. With such purpose TESAT has implemented MOIS and customized the generation of the different operational products like the links and different parameters execution requests.

The following graph shows the latest links statistics of the TDP1 system.

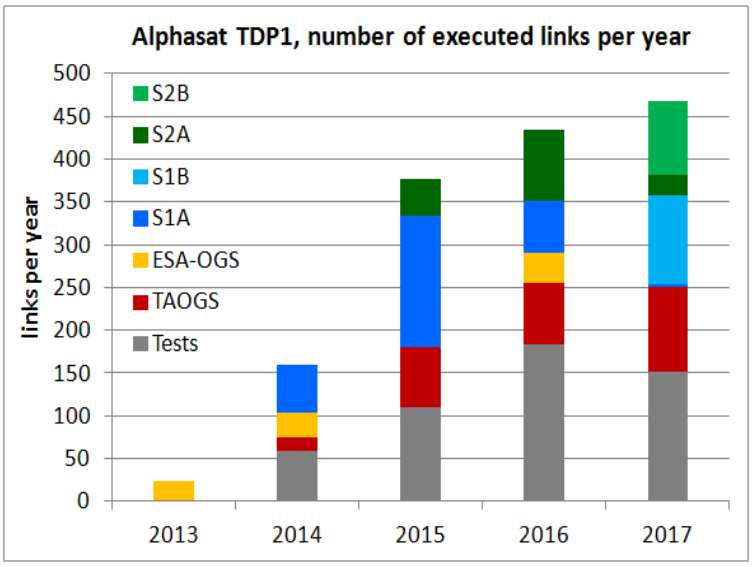

Figure 1: Links between the LCT located on Alphasat and the link partners (S- are the Sentinel earth observation space crafts from the European Copernicus program, ESA OGS is the optical ground station of the European Space Agency [1].

The TDP1 planning is a weekly operational product; every week the tasks to be executed in the upcoming week by the TDP1 LCT and Ka-band are planned. The planning week contains also the products for the counter terminals (if it is requested) and the different flags for allowing the recording on ground of the User Data or recording the auxiliary telemetry of the LCT. The MCC (operated by DLR GSOC) performs a syntax check and the final de-conflicting of the activities before delivering the planning to the different spacecraft control centers for the uplink of the TCs. The flight dynamic inputs are also included in the link commanding files before final delivery. For more details on the link planning itself please refer to [3].

The following diagram shows the interfaces involved in the TDP1 planning and commanding system.

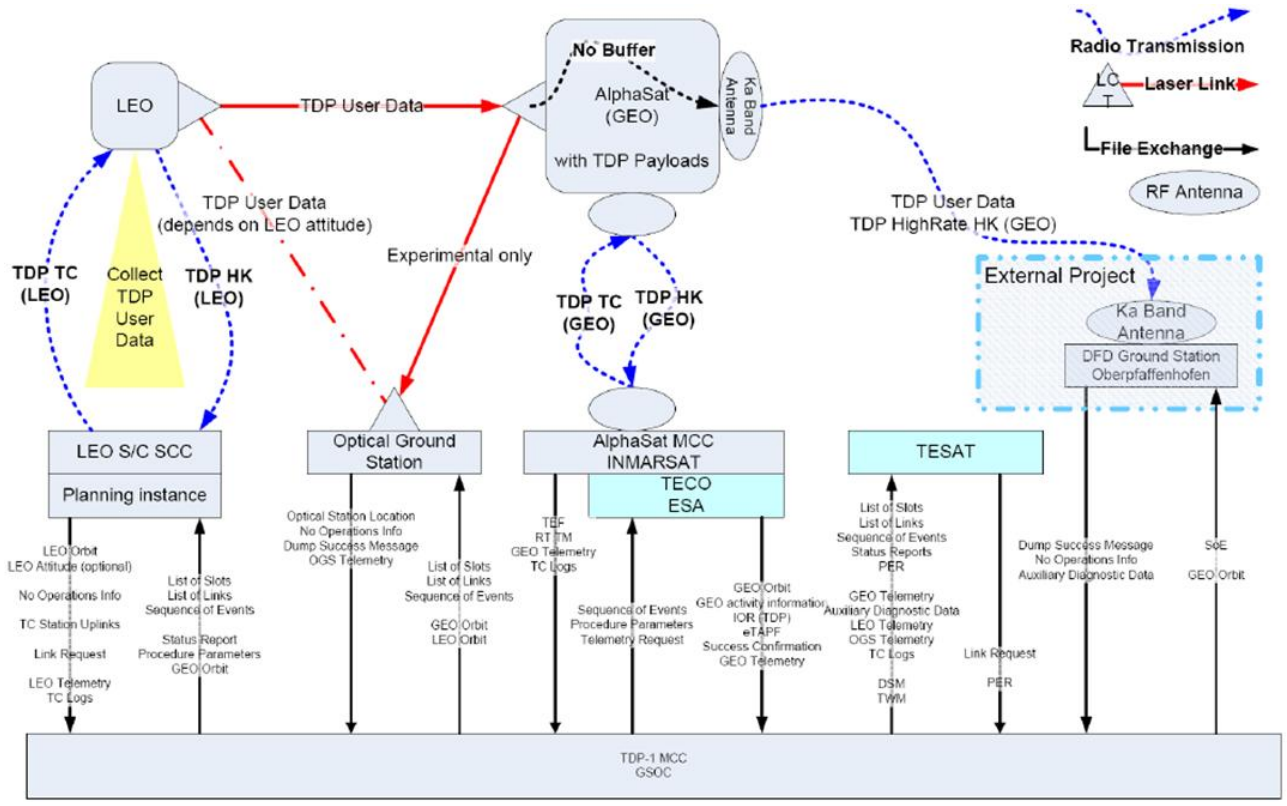

Figure 2: TDP1 MCC System definition [4].

TDP1 and T-AOGS are operated by TESAT Spacecom under contract of the German Aerospace Center (DLR) and in cooperation with European Space Agency (ESA) and Inmarsat.

III. Operational products generation

In 2013 TESAT started the generation of the first operational inputs for the TDP1 LCT and Ka-Band on board of Alphasat. In 2014 the first operational products for Sentinel 1A were also delivered; in the following years other Sentinels joined to the relay (Sentinel 2A, 1B and 2B) with the corresponding optimization of the commanding I/Fs.
During the first 2 years the planning was accomplished via manual ingestion of the inputs files and different links requests. In order to reduce potential human mistakes and provide a more stable planning process, TESAT implemented a standard SW already in use by many mission control centers. This SW allows importing mission relevant information like slot-lists and operational constraints (either from S/C or from the LCTs itself) which need to be considered by the mission planner. The Manufacturing and Operations Information System (MOIS) implementation at TESAT was supported by RHEA.
All the relevant operational information can be displayed graphically in an integrated scheduler (Gantt-view) which allows to the mission planner the overview of all the tasks and the corresponding execution/duration times.
The activities can be anchored on one particular task and be shifted in time accordantly. This is an important feature for re-scheduling the activities. Another big advantage of the system is that any operational product can be exported and exchanged with the customer without manual transfer.

Links and tasks for Alphasat and the LEO terminals can be planned and processed in the same plan taking into account the availability of all relevant resources for the planning period and displaying them into the Gantt view. All events can also be displayed chronologically in form of a table in an “Activity view”. More over the activation of filters in this view enable the user to show dedicated details of the planned activities for a particular LCT. This option simplifies the operator´s task of re-scheduling only one counter terminal if it is requested.

The SW has an integrated export functionality to export the activities from the plan in Excel format for further processing, analysis or other kind of print out. It is also possible to export planned links and tasks – all or only dedicated one – and save them for future re-use in new planning.
The tool provides the possibility of doing checks for the planned links and tasks, like the availability of the laser communication terminals, slots for the corresponding links, overlap of the planned products themselves or with non operational zones.
After the weekly planning is finished the SW can automatically generate the operational products, like PERs or link request. In this way it can be guaranteed that the exported products are free of syntax errors and planning failures are minimized.
The GSOC MCC weekly planning cycle allows TESAT to execute a dry -run check prior to the official submission date. This check includes e.g. planning constraints like non-operational zones, slot-lists and syntax checks. GSOC MCC provides the result of such dry-run to TESAT as SoE (sequence of events). This pre-check allows the TESAT planner to identify any potential conflict (GSOC always have the most actual operations information and optimize or re-schedule the tasks supported by MOIS).
The inputs for the planning itself have different sources, i.e. that there are experiments, maintenance activities or even tests for supporting trouble shooting activities. Therefore it is necessary also to implement a dynamic process for generating the corresponding documentation and configuration items. TESAT has established an internal process to support mission planning by specifying requirements for dedicated missions in technical test procedures. Based on these test procedures the mission planner writes the so called "execution procedures". The execution procedure describes how the mission requirements are fulfilled by the mission planning, commanding the laser communication terminals and Ka-Band accordingly with the appropriate sequence of PPFs, link requests and adequate schedule. All these documents are subject to a review and approval process contributing to stable and reliable mission planning.

III Conclusion

The results and experience acquired serves for further development of products tailored to the needs of future applications such as optical direct to Earth, Gbps feeder links, constellations or small and agile satellites optical down link to cubesats. It also allows us a better understanding of the future operational needs of the customers, for supporting them not only developing the operational Concept (ConOps) but also during the hardware and software design and development.
Further enhancement of the operational product generation lead TESAT to look for a more automated process. The implementation of a scheduling system, used already by many mission control centres (MOIS), which provides a very reliable and efficient means for generating and exchanging the laser communication operational products with the customers.
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References

[1] F. Heine et al, The European data relay system and Alphasat to T-AOGS space to ground links, status and achievements in 2017, Spie2018, http://photonics.org/
[2] K. Saucke et al, "The TESAT Transportable Adaptive Optical Ground Station and the operational experiences", ICSO 2016, Biarritz : http://icsoproceedings.org/
[3] G. Rossmanith et al "Laser Communication in Space: The TDP-1Mission Control Center and its current operational experience", SpaceOps Conference, Daejeon (2016)."
[4] R. Ballweg et al., "TDP1 Ground System Design", AIAA SpaceOps Conference, Pasadena, CA (2014-1626)